

AVERAGED EVOKED RESPONSES TO LIGHT AND ODORANT  
UNDER CERTAIN AND UNCERTAIN CONDITIONS

An Abstract of a Thesis by  
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The Problem. To determine if the averaged evoked response to odorants was similar to the late positive component in the averaged evoked response to lights, both light and odorant were presented under two conditions to see if they would both occur under the same experimental condition and both be absent under the same condition.

Procedure. A light and an odorant were presented to human subjects under two conditions, when the subject knew which of the two stimuli would be presented (certain condition) and when the subject did not know which of the two would be presented (uncertain condition). The averaged evoked responses to these two stimuli under the two conditions were compared.

Findings. The late positive component in the response to light was significantly larger in the uncertain than certain condition as predicted. The response to odorants, however, was not found consistently or exclusively in the uncertain condition.

Conclusions. The results are somewhat inconclusive as the response to odorant was not found consistently in at least one of the two conditions. However, the results do not support the hypothesis that the evoked response to odorant and the late positive component in the evoked response to light occur under the same conditions.

Recommendations. A procedure under which the averaged evoked response to odorants can be reliably produced should be found before further attempts at determining its other properties are made. An exact replication of the study by Allison and Goff (1967) in which the evoked response to odorant was reported to be reliably produced is suggested.

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A Thesis  
Presented to  
The School of Graduate Studies  
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Of the Requirements for the Degree  
Master of Arts

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Lois J. Pokorny  
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## CHAPTER I

### INTRODUCTION

The electroencephalograph (EEG) is generally used to monitor the spontaneous electrical activity of the brain, that is, the ongoing activity of the brain independent of specific sensory stimulation. If a stimulus, such as light, tone, or odor is presented to the subject, the brain's electrical response (evoked potential) to the stimulus may be recorded on the EEG. Such a response is difficult to detect and interpret, however, because it is always partially submerged in the spontaneous activity. Techniques have been developed in the last 15 years to average across a number of presentations of a stimulus with the effect that the activity which is random with respect to the stimulus presentations is assumed to average to zero while the events which occur reliably to each presentation of the stimulus summate and thus become more distinct. The averaging technique has been used by numerous investigators to study evoked potentials to auditory, visual, and somatosensory stimuli (Regan, 1972; Shagass, 1972).

The sensory evoked potentials to stimuli from these modalities are roughly similar, as can be seen in Figure 1. Early small components precede a larger positive component which occurs at a latency of approximately 200 msec. Investigators generally agree that the early small components to

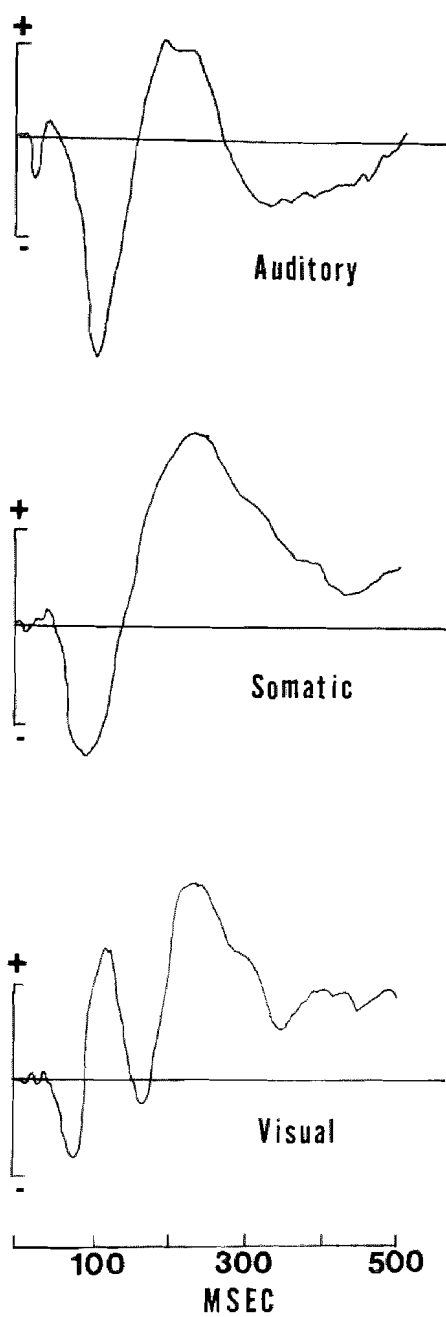


Figure 1. Averaged sensory evoked responses to auditory, somatic, and visual stimuli. From Vaughan, 1969.

visual and somatosensory stimuli are generated in the corresponding primary sensory cortex (Shagass, 1972). The early components of the auditory response have been attributed to muscle artifacts by some researchers (Bickford, Jacobson, & Cody, 1964). However, most investigators now consider the early components to auditory stimuli to be generated by the auditory system (Lindsey, 1971).

The positive component at about 200 msec, occurring to stimuli of the three modalities, is maximal at the vertex, and is called either the vertex response due to the cortical location or the V-potential due to its large V-like form. The source of this component is currently under study, with the debate centering around the question of the specificity or nonspecificity of the response. The term nonspecific refers to neural populations whose function is independent of the modality of the stimulus (Regan, 1972). The observations that the vertex response is bilaterally distributed and that it occurs with only slight differences in distribution and latency to stimuli of the three modalities suggests a nonspecific source for this component (Davis, Osterhammel, Wier, & Gjerdingen, 1972). Davis and his associates (1972) suggested that the response may be transmitted along extralemniscal, bilaterally projecting reticular and thalamic pathways. Other evidence, however, indicates that the response is specific in nature (Williamson, Goff, & Allison,



1970; Vaughan, 1969).

The components of the sensory evoked responses that are included in Figure 1 and that were discussed above are described by Vaughan (1969) as being obligatory in nature. The responses will always occur to a stimulus of sufficient intensity although the amplitude, and to some extent the form and latency of the response, are influenced by stimulus and subject variables. In general the amplitude of the response increases as the intensity of the stimulus or attention of the subject increases (Regan, 1972; Shagass, 1972).

A still later component, not shown in Figure 1, is often termed the late positive component (LPC). This component has been observed to occur to visual, auditory, and somatosensory stimuli; most of the research concerning this component has used visual and auditory stimuli. The LPC is not obligatory in nature (Vaughan, 1969); the component is generally not present to a regularly occurring stimulus to which the subject is not directing his attention. It is present under a variety of conditions however (reviewed by Karlin, 1970) including 1) when the subject is highly attentive to the stimulus, 2) when there occurs an unpredictable change in stimulus qualities, and 3) when the stimulus delivers a relatively large amount of information to the subject. Figure 2 compares auditory evoked responses which did and did not give rise to the LPC. The latency of this

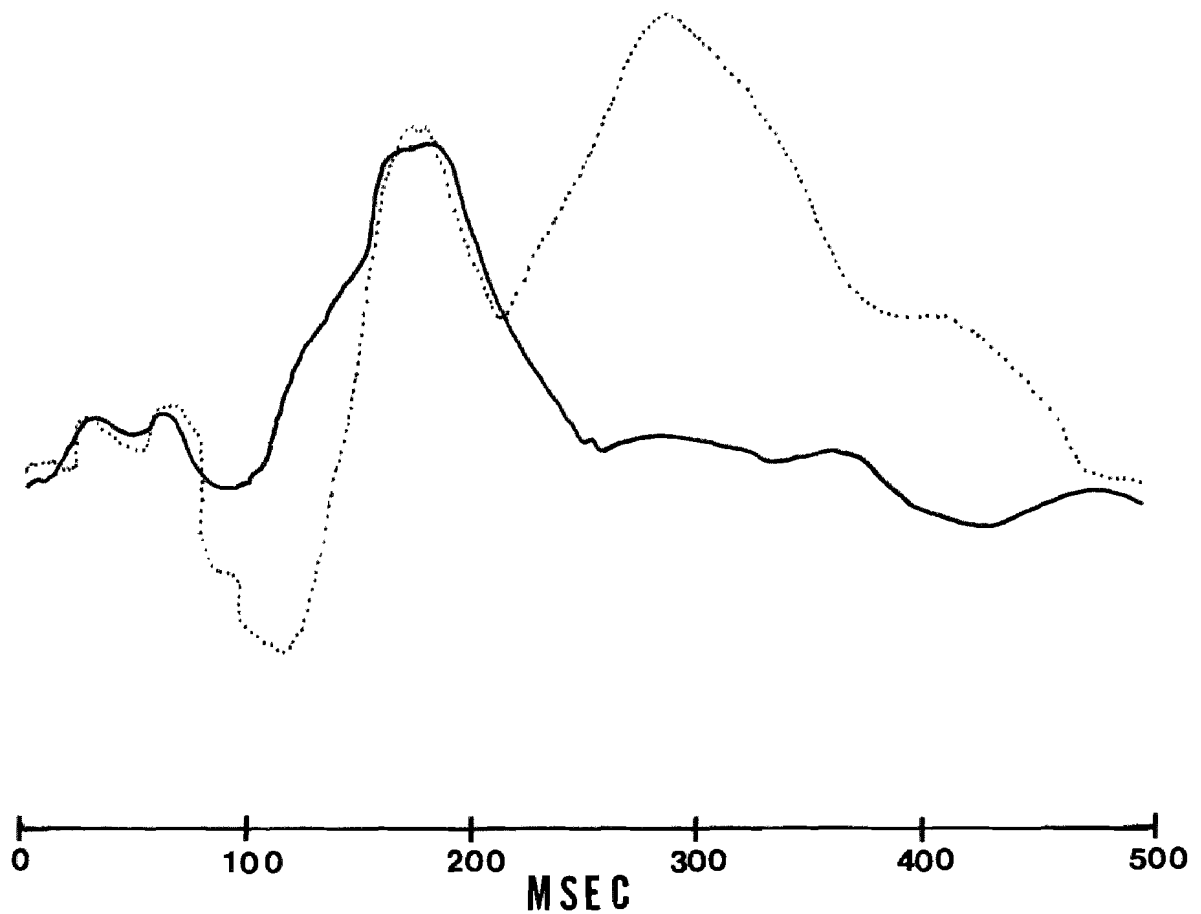


Figure 2. Comparison of auditory evoked responses without LPC (solid line) and with LPC (dotted line) produced under conditions when the subject was and was not certain, respectively, beforehand of the modality of the stimulus that would be presented. Positive up. From Sutton, 1969.

component is variable, generally appearing between 250 and 550 msec, the latency depending on the experimental conditions (Ritter, Simson, & Vaughan, 1972). It is found in largest amplitude at the vertex regardless of the modality of the stimulus; the distribution is somewhat different from the vertex response described above. Vaughan (1969) used volume conduction models to study the topographical distribution of the component to auditory and visual stimuli. He concluded that these potentials are probably generated in the parieto-temporal cortex, and thus are presumably nonspecific.

In contrast to the many studies concerning evoked potentials to auditory, visual, and somatosensory stimuli, the evoked potential to olfactory stimuli has received little attention due in part to greater difficulty in stimulus control and less attention to the olfactory sense in general. Only two groups of investigators, Finkenzeller (1966) and Allison and Goff (1967) have reported averaged evoked responses to odorants<sup>1</sup> (See Figure 3). The responses

<sup>1</sup>Smith, Allison, Goff, and Principato (1971) in a later study determined that the response they were observing (Allison et al., 1967) was mediated not by the olfactory system but by the trigeminal system. These investigators conducted a study of persons having surgical lesion of the olfactory tract or trigeminal nerve. The odorant evoked potential was obtained only when the trigeminal nerve was intact; the condition of the olfactory tract did not affect the response. The trigeminal nerve, the fifth cranial nerve,

described in both of these reports are positive going potentials, are largest at the vertex, and occur approximately 500 msec following the presentation of the odorant. Comparison of the odorant evoked response (Figure 3) and the sensory evoked responses to stimuli of other modalities (Figure 1) shows the response to odorants occurring later and being less complex in form. The distribution also differs, as Allison and Goff (1967) pointed out in their brief comparison of the odorant response to vertex responses evoked by somatosensory and auditory stimuli. The odorant response was distributed more vertex posteriorly and was small frontally compared to the vertex responses of the other two modalities.

The response to odorants does, however, resemble the late positive component. The LPC to auditory stimuli is described as being more posterior than the vertex response (Vaughan & Ritter, 1970). As noted above, the response to odorants is also more posterior than the vertex response to auditory stimuli. The distribution of the LPC to auditory stimuli and response to odorants would then seem to be similar. The latency of the response to odorants (500 msec)

innervates the mucous membranes of the nasal cavity. This nerve was traditionally thought to mediate the stinging sensation that often accompanies strong odors, but other evidence indicates it responds to less intense odors (Beidler & Tucker, 1955; Tucker, 1962; Tucker, 1963).

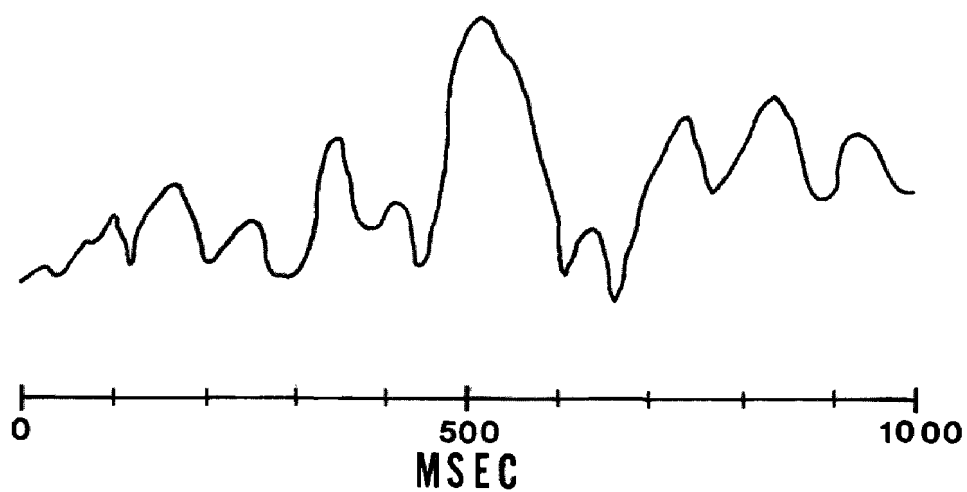


Figure 3. Odorant evoked response averaged over 30 presentations of amyl acetate. Positive up. From Allison and Goff, 1967.

falls within the range of latencies for the observed LPC's (250-550 msec). Figure 4 shows an LPC that was evoked when the subject expected but did not receive an auditory stimulus. This figure which shows the LPC without the earlier components as was the case in Figure 2, allows better comparison of the form of the LPC and the odorant evoked response. Figure 4 includes the response to an auditory stimulus presented at 0 msec and the LPC when the subject was expecting but did not receive a second stimulus at 580 msec. The general form of the LPC and odorant evoked response is similar. Thus in distribution, latency, and general form the odorant response seems to resemble the late positive component to stimuli of other modalities.

The odorant evoked response can also be compared to the LPC in terms of the conditions under which the responses can be obtained. As noted above, the sensory evoked response is obligatory, the LPC is not. The LPC is generally not present when the stimulus occurs regularly and the subject is not attentive to the presentations. Allison and Goff (1967) reported they obtained the response when presenting the odorant stimulus at a six second fixed interval, conditions under which an LPC would not be expected. Our attempts to replicate their results however (Grundvig & Pokorny, unpublished data) have been largely unsuccessful, but produced some interesting results. A total of 25

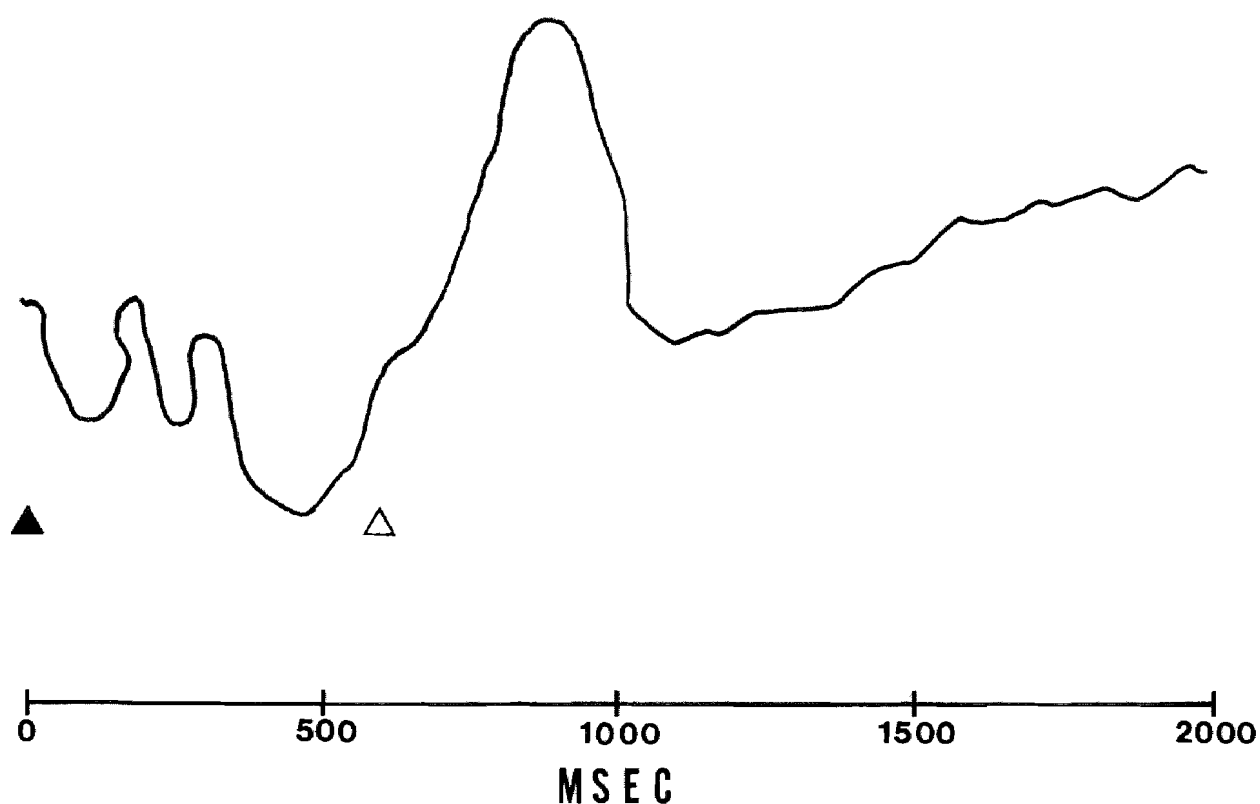


Figure 4. Average response waveforms showing LPC evoked when the subject might have received an auditory stimulus (click) but did not. Filled-in triangle indicates when a click was delivered, open triangle indicates when the subject was expecting a second click. Positive up. From Sutton, Tueting, Zubin, and John, 1967.

different subjects were run, with only two producing large evoked responses, and several others producing small rather nondescript responses. No responses were apparent for the remaining subjects. The two subjects who produced the large responses were the two researchers who were presumably more highly motivated than the other subjects and directed their attention more fully to the task. Attention to the stimulus is a variable found to correlate positively with the LPC.<sup>4</sup>

To further determine if the odorant evoked response is obtained under the same conditions which evoke an LPC to stimuli of other modalities a study similar to the one conducted by Sutton, Braren, Zubin, and John (1965) was designed. Sutton et al (1965) studied the effect of stimulus uncertainty on evoked potentials. Stimuli were delivered in pairs. The first member of the pair served as a cueing stimulus and the second as the test stimulus. There were two kinds of pairs. In one kind a cueing stimulus was followed by a test stimulus that was always a light or always a sound. The subject then was certain of the modality of the test stimulus before it occurred. In the second kind of pair a different cueing stimulus was followed by a test stimulus which was either a sound or a light. The subject was uncertain as to the modality of the test stimulus. During the interval between the cueing and test stimuli



the subject stated his guess as to the sensory modality of the next stimulus. Figure 2 shows the average evoked response curves to test stimuli. The late positive component whose latency at peak amplitude is about 300 msec is present only in the uncertain condition.

In the experiment reported here an odorant stimulus is one of the test stimuli. Three lights serve as cueing stimuli. The first is always followed by the test light (certain), the second is always followed by the test odor (certain), and the third is followed 50 percent of the time by the test light and 50 percent of the time by the test odor (uncertain). If an LPC occurs to the light in the uncertain condition, but not to the light in the certain condition, Sutton's results will be replicated. And if the odorant response occurs to the odor in the uncertain condition but not in the certain condition, the contention that the response to odorants is similar to the late positive component to other stimuli will be supported.

## CHAPTER II

### METHOD

#### Subjects

Five female students at the Knoxville, Iowa Public High School were paid to serve as subjects. They ranged in age from 15 to 17.

#### Apparatus

The equipment used during the experiment is diagrammed in Figure 5. Abbreviations used in Figure 5 to represent equipment components are identified in the text which follows. The subject was seated in a comfortable padded recliner chair in a room separate from the experimenter and the bulk of the equipment.

Physiological monitoring apparatus. A Grass Model 6 Electroencephalogram (EEG) monitored and amplified brain electrical activity. A pneumograph was used to monitor respiration; the respiration record was displayed on an EEG channel.

Light presentation apparatus. Three small stimulus lights, a green(G), a red (R), and a white (W), were arranged horizontally above a larger gold(Gd) stimulus light. All were mounted on a 10" X 12" card (C) positioned about five feet in front of the subject. On the card "precedes light" was printed under the green light, "precedes odor" was printed under the red light, and "precedes light or odor"

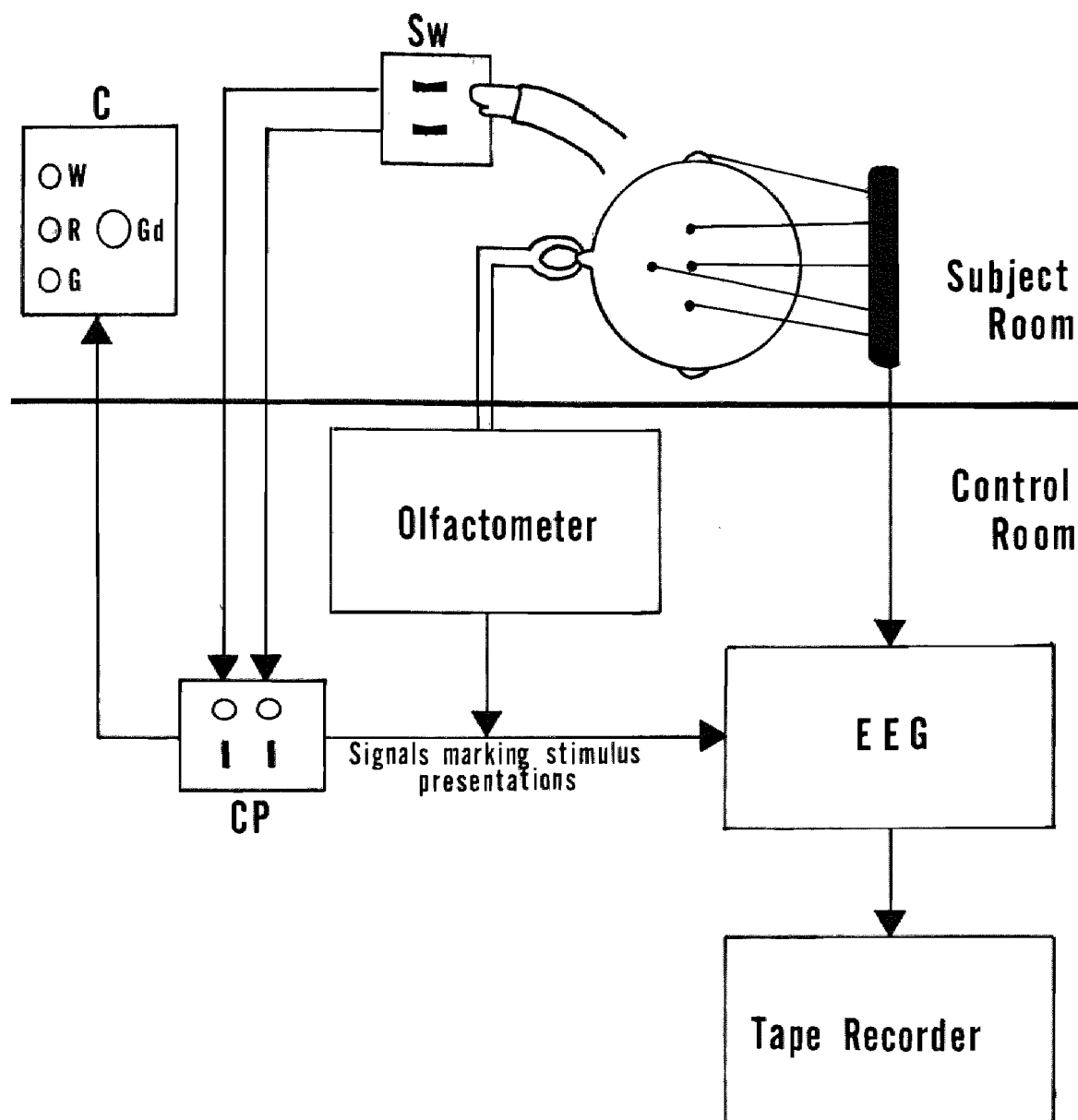


Figure 5. Block diagram of the equipment used during the experiment.

was printed under the white light. Switches on a panel (CP) in the control room allowed the experimenter to manually turn the lights on and off. When the gold light was on voltage was sent to the EEG and subsequently to the tape recorder to mark the time of presentation.

Odor presentation apparatus. The olfactometer apparatus diagrammed in Figure 6 (pages 11 and 12), and described previously (Grundvig, Dustman, & Beck, 1967), was used to present the odor to the subject. This apparatus permitted a means of marking the onset of odor presentation to allow averaging across presentations, allowed measurement of the odor presented to the subject, and reduced the influence of background odors in the subject's environment. The apparatus delivered air flow to the subject throughout the session at a rate of 16 liters per minute. This flow rate was sufficient that the subject used the air from the apparatus as her air source during the session; background odors in the room therefore had minimal interfering effect. The subject inserted the nose pieces in her nostrils, and inhaled the air through her nose and exhaled through her mouth. The nose pieces were conical in shape. They fitted virtually any nose size, and insertion of them in the nostrils effectively blocked the passage of air from any but the internal source. The subject was given at least five minutes to practice breathing from the apparatus and three presentations

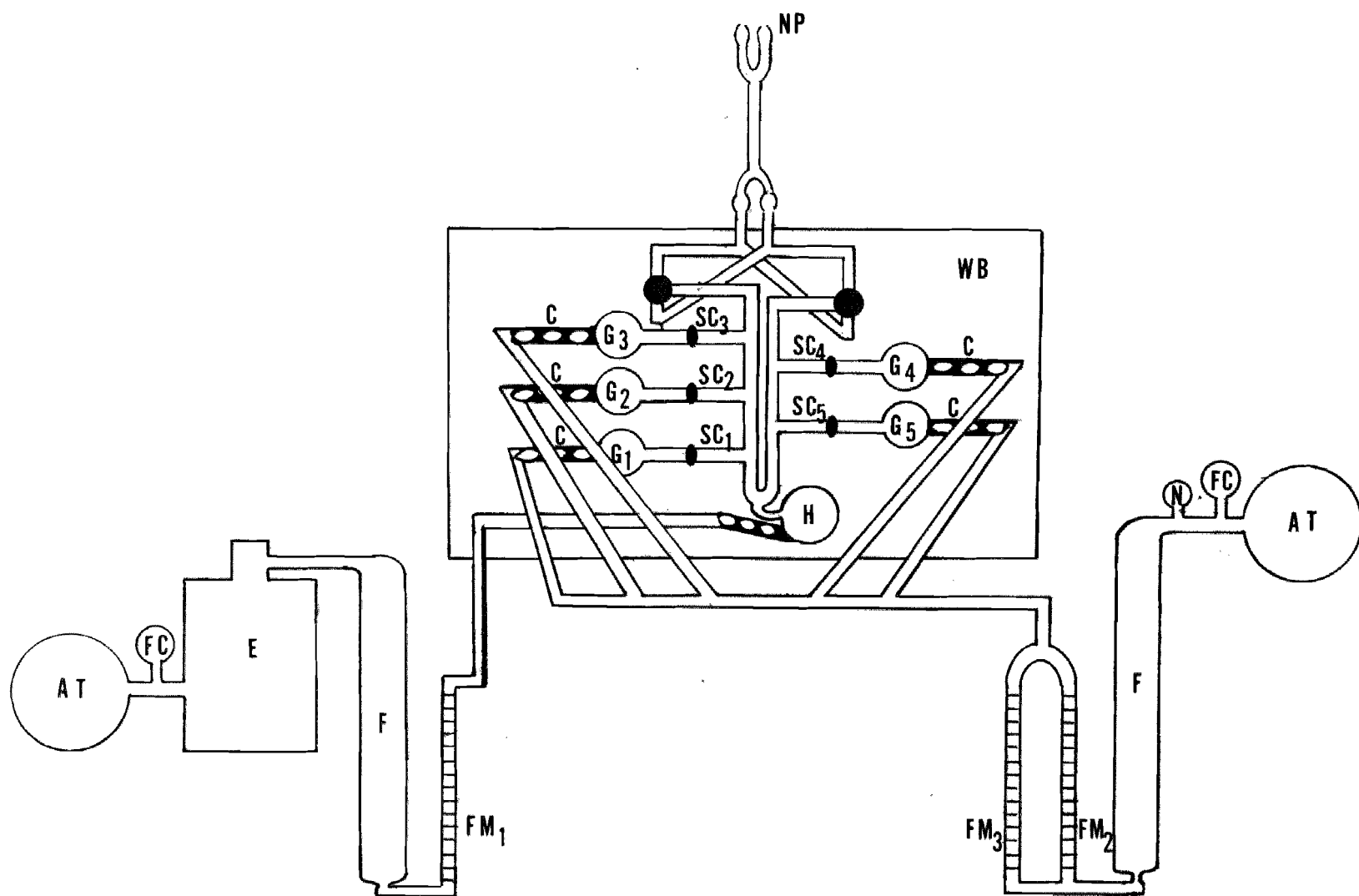


Figure 6. Schematic representation of odor delivery apparatus, adapted from Grundvig, 1966.  
Abbreviations are identified in the text and on the following page.

Figure 6. Schematic representation of odor delivery apparatus.

AT	Breathing air tank
C	Temperature equilibration coil
E	Air flow equalizer (carboy)
F	Filter unit
FC	Flow control guage
FM	Flowmeter
G	Gas washing bottle
H	Humidifier
N	Needle valve
NP	Nosepieces
SC	Stopcock
WB	Water bath

of the odor before the session began.

The apparatus components that are included in Figure 6 are described in the following discussion of olfactometer function. The total air flow through the apparatus was composed of a dilution stream (14 liters/min) and a saturator stream (2 liters/min). The air source for each stream was a tank of breathing quality air (AT). The flow rate of each stream was controlled by a metal oxygen type flow control and pressure guage (FC). A needle valve (N) was included in the saturator stream to provide for more precise control, and a five liter carboy (E) was included in the dilution stream to help equalize the air pressure. Each stream passed through a filter unit (F) packed with layers of calcium chloride, silica gel, and activated charcoal with glass wool interspersed before and after each chemical layer. Each stream then passed through a Manostat Corporation "predicability flowmeter" (FM). The dilution stream had a 18 liter per minute capacity flowmeter (FM<sub>1</sub>) and a 2000 milliliter per minute capacity flowmeter (FM<sub>2</sub>) was used for the saturator stream. After leaving the flowmeter, the dilution stream then bubbled through a flask of distilled water (H) to humidify the air. After leaving the flowmeter the saturator stream could be directed through one of five gas washing bottles (G<sub>1-5</sub>) by the position of the stopcocks (SC<sub>1-5</sub>). The gas washing bottles were fitted

with fritted discs to disperse the air into fine bubbles and saturate the air with the odor vapor. The air passed through a spiral glass coil (C) before reaching each bottle. The coils were included to increase the surface area in contact with the water bath (WB) when it was used to control the temperature of the air. In the present experiment the air was presented at room temperature.

Bottles 3-5 were not used in this experiment, and stopcocks 3-5 remained closed. Bottle 1 contained saturated amyl acetate and bottle 2 contained distilled water. When odor was not being presented to the subject stopcock 2 was open, thus directing the saturator stream through bottle 2, containing distilled water. To inject odor into the system the experimenter simultaneously opened stopcock 1 and closed stopcock 2, thereby directing the saturator stream into the bottle containing the odorant. Downstream from the gas washing bottles the saturator stream joined the dilution stream. The air flow was directed into the subject's room through a five foot length of teflon tubing. A Y-tube, with nose pieces (NP) fitted on the arms of the Y, directed the flow into the subject's nostrils.

The flow rate of the dilution stream was 14 liters per minute; the flow rate of the saturator stream was two liters per minute. Concentration of the odor was thus calculated to be 12.5 percent of saturation. The opening of



stopcock 1 placed a signal on the magnetic tape to mark the point of stimulus presentation for later data analysis.

Subject response apparatus. (See Figure 5). Two toggle switches (Sw) were mounted on the right arm of the subject's chair. One was marked "light," the other was marked "odor." Lights on the control panel (CP) lit when the switches were in the ON position, indicating to the experimenter the positions of the switches.

Data storage apparatus. The brain activity and the signals marking the presentation of odor or light under the two conditions were fed from the EEG to a seven channel Bell and Howell FM tape recorder model VR-3200

Data analysis apparatus. A block diagram of the equipment used for data analysis appears in Figure 7. The stored EEG and stimulus signals were led from the tape recorder into an analog-digital (A/D) converter and multiplexer control interfaced to a Digital Equipment Corporation PDP-8/e computer. A computer program initiated A/D conversion of EEG voltages .500 seconds prior to the onset of each stimulus and at successive 1 msec intervals thereafter for a period of 2.500 seconds following the signal. The values were summed and divided by the number of stimuli, thus yielding averaged evoked responses.

The averaged responses were then displayed on a Hewlett Packard oscilloscope for inspection and a copy printed

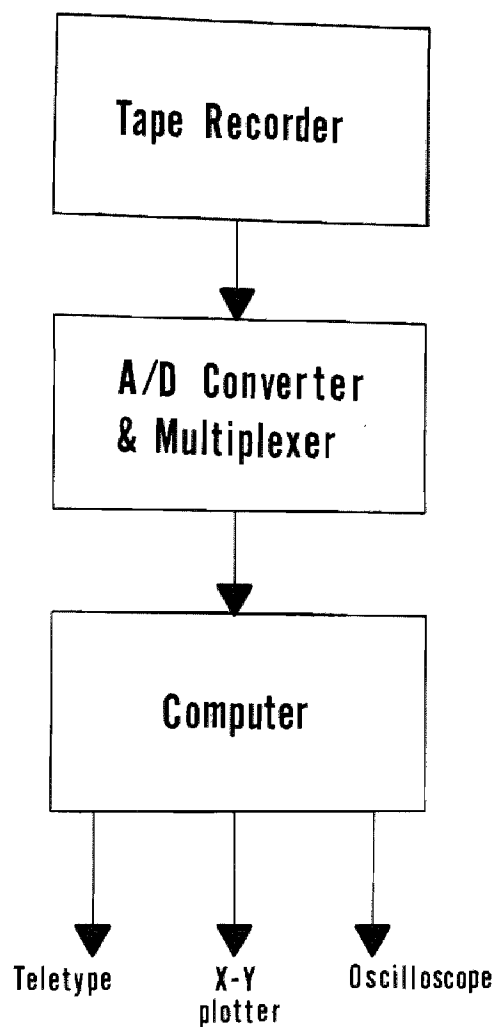


Figure 7. Block diagram of the equipment used for data analysis.

on paper by a Houston Instruments X-Y plotter. The numerical values of the points comprising the responses were printed by the teletype. The instruments were not calibrated for absolute voltages and thus the values represent points on an interval scale.

### Procedure

The subject's scalp was cleaned with acetone, and silver cup electrodes were attached with Grass EC-2 electrode cream at Fz, Cz, C3, and C4 according to the international "10-20" system (Jasper, 1958). Recordings were monopolar, with the electrical activity from the right ear lobe serving as reference. The pneumograph was positioned around the subject's chest.

The subject was seated in the reclined position in the chair. Nose pieces from the olfactometer were inserted in the subject's nostrils. The subject breathed air continuously through the nose pieces. The air was odorless except for brief intervals when odor was present.

The subject was instructed that the small lights would serve as cues that another stimulus, a test stimulus, was about to occur. The gold light and an odorant (amyl acetate) served as test stimuli. The subject was further instructed that the green light would always precede the gold stimulus light, the red light would always precede the odor, and the white light would precede the gold light

50 percent of the time, and the odor 50 percent of the time. To help the subject remember the conditions of the stimulus pairs, under the green light was printed "precedes light," under the red light was printed "precedes odor," and under the white light was printed "precedes light or odor."

The subject was instructed to watch the cueing lights during the session. A trial began when one of the three cueing lights was turned on. The subject then indicated which of the two test stimuli, light or odor, she expected would follow by switching the appropriate toggle switch on the arm of the chair to the ON position. No subject ever failed to indicate that light would follow the green cue light or that odor would follow the red cue light.

The experimenter operated all stimulus controls manually. At the start of each trial the experimenter turned on one of the three cueing lights, and 3-5 seconds later the experimenter presented the test stimulus either by positioning a switch to turn on the gold light or by turning the appropriate stopcocks to present the odor. The action of presenting the test stimuli also placed a signal on the recording tape which was later used to trigger the computer for summing and averaging the evoked responses. The experimenter watched the subject's respiration as it was monitored by the pneumograph and presented the test

stimulus as the subject began to inhale. Duration of the test stimulus ranged from .3 to .6 seconds. The cueing light remained on during the trial, and was turned off approximately four seconds after the test stimulus. After the cueing light was turned off, signalling the end of the trial, the subject returned the toggle switches on the arm of the chair to the OFF position. The four pairs of stimuli, green followed by light, red followed by odor, white followed by light, and white followed by odor were presented in predetermined random order so that each pair was presented 30 times during the session. The minimum interval between trials was 20 seconds. After twenty seconds the experimenter began to watch the subject's respiration record and presented the stimulus as soon as the record indicated that the subject was sitting quietly and was beginning to inhale. The maximum interval was approximately 40 seconds. A break of approximately ten minutes was taken in the middle of the session to allow the subject to stretch and relax. Length of the experimental session ranged from one to one and a half hours.

## CHAPTER III

### RESULTS

Visual inspection of the responses from the four cortical locations reveals that both the LPC to light and the OER were largest at the Cz (vertex) lead. This finding is in agreement with the reports in the literature that the OER (Allison and Goff, 1967; Finkzeller, 1966) and the LPC (Regan, 1972) are largest at the vertex. Further discussion of the present results will be in terms of the responses recorded from the Cz lead. The choice of this location for discussion is in keeping with most of the literature on the LPC and all of the literature on the odorant evoked response. The averaged responses to light and odor in the certain and uncertain conditions recorded at Cz for each subject are displayed in Figure 8a-e.

#### Responses to light

The components of the evoked response to visual stimuli are marked in Figure 8a-e. The peak representing the vertex response is marked V, the negative peaks preceding and following the vertex response are marked  $N_1$  and  $N_2$  respectively, and the peak representing the LPC is marked L. It should be noted that the considerable diversity in form of evoked responses between subjects makes it often difficult to distinguish the various components (Regan, 1972).

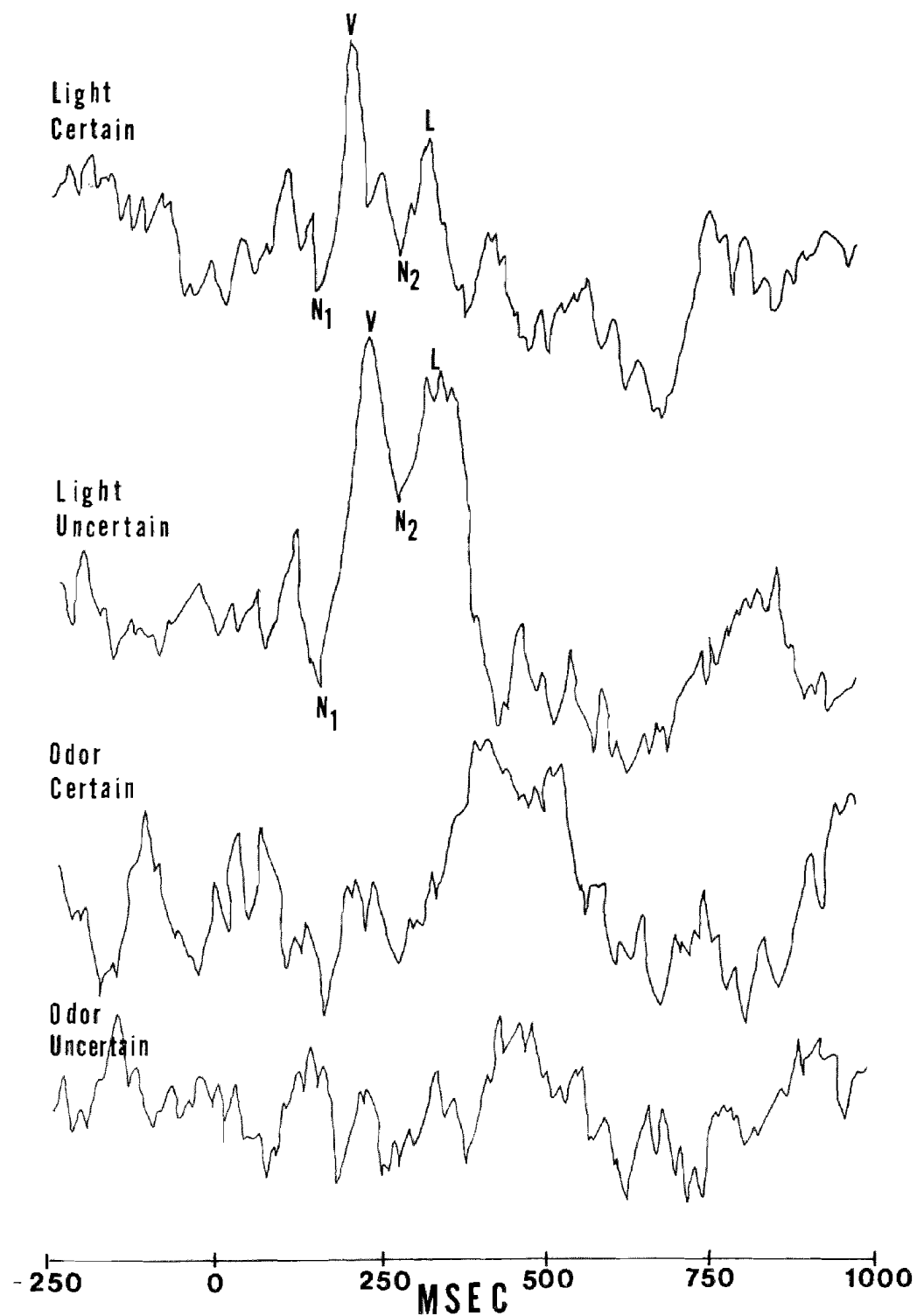


Figure 8a. Average evoked responses of subject 1, recorded at the vertex, positive up.

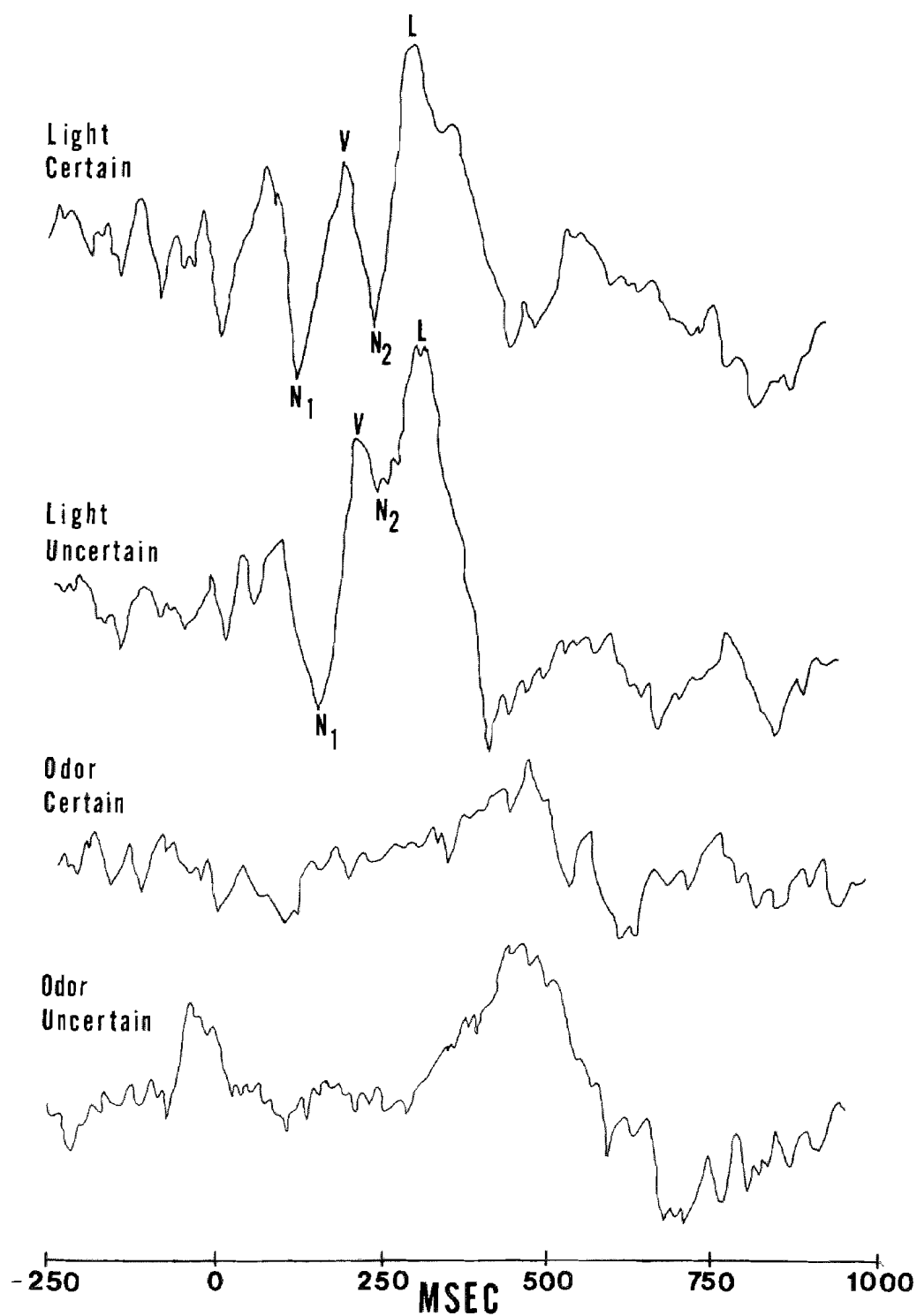


Figure 8b. Average evoked responses of subject 2, recorded at the vertex, positive up.



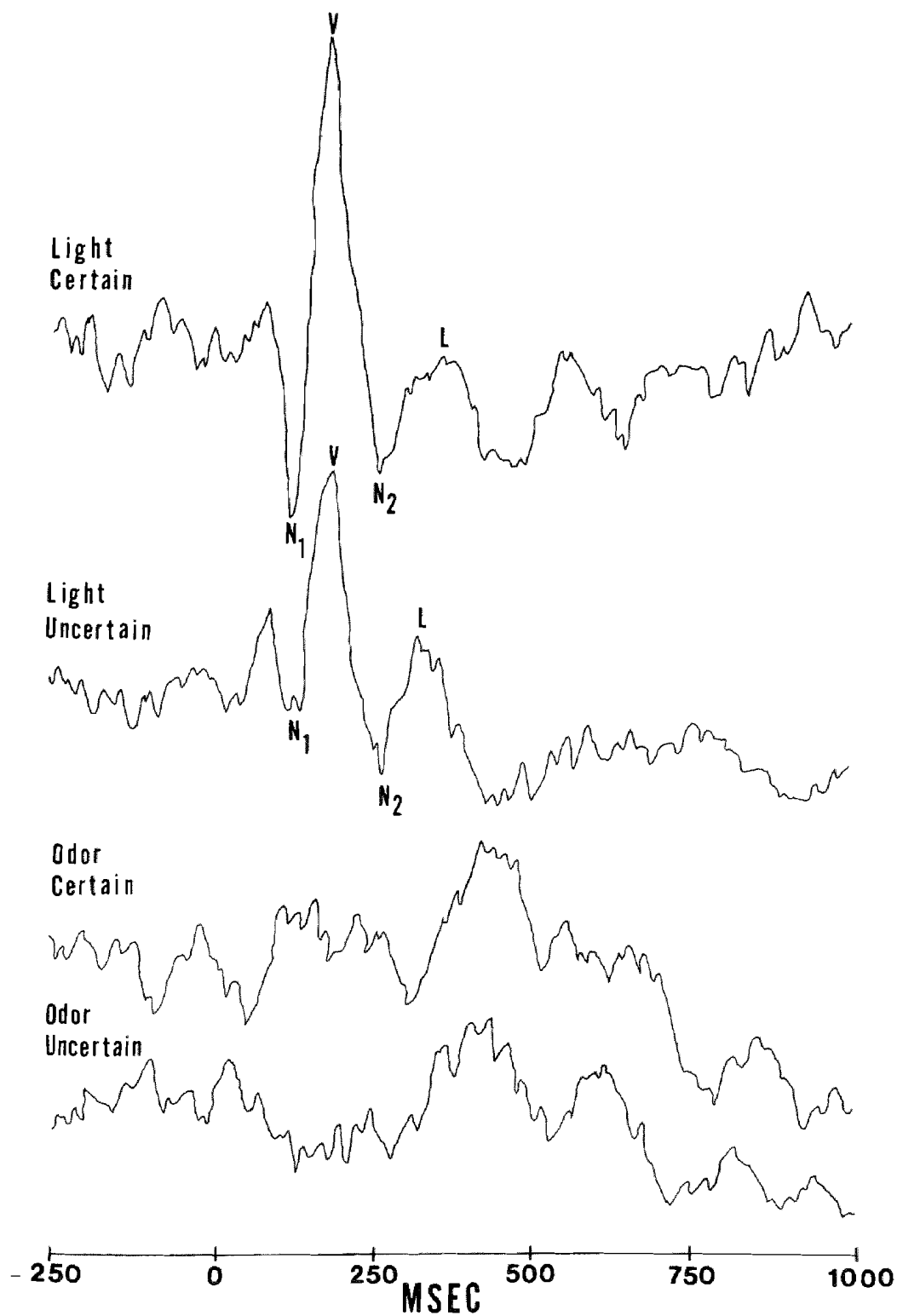


Figure 8c. Average evoked responses of subject 3, recorded at the vertex, positive up.

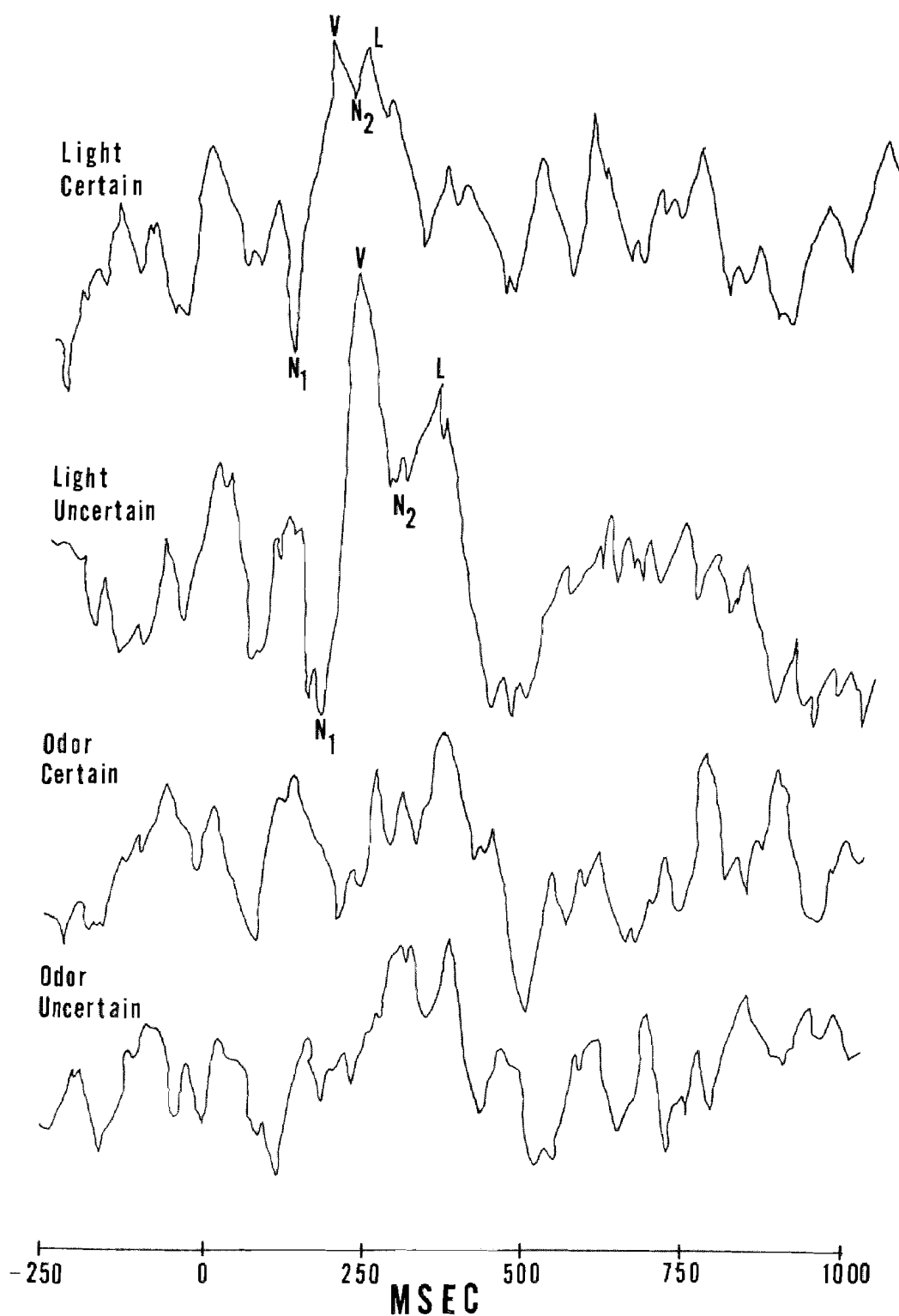


Figure 8d. Average evoked responses of subject 4, recorded at the vertex, positive up.

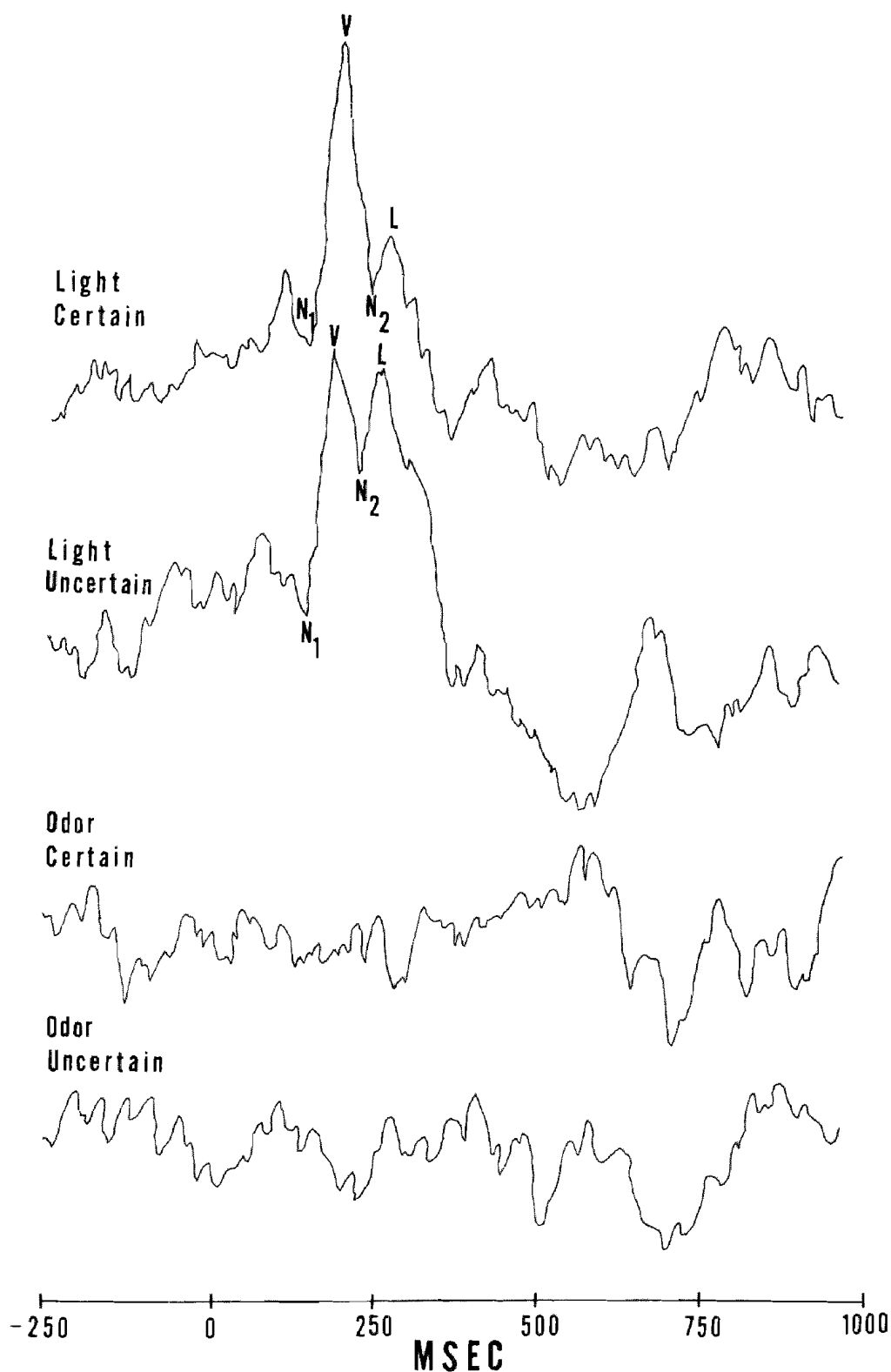


Figure 8e. Average evoked responses of subject 5, recorded at the vertex, positive up.

The amplitudes and latencies of the peaks described above are displayed in Table 1. The amplitudes represent points on a interval scale, corrected for baseline differences. The baseline was calculated for each subject in each condition by averaging the last 50 data points on the averaged responses preceding stimulus onset. That is, the 50 data points occurring in the interval ranging from 50 msec before the stimulus to stimulus onset were averaged. This baseline amplitude was subtracted from the amplitudes of the peaks to yield the base to peak amplitudes presented in Table 1. The latencies represent the time in seconds from the onset of the light stimulus to the occurrence of the peak. One tailed  $t$  tests for matched samples (Hays, 1968) between certain and uncertain conditions were calculated to determine if the amplitudes in the uncertain condition were significantly higher as predicted. A significant value,  $t(4)=3.14, p<.05$ , was found for the LPC; non significant values were found for the other base to peak measures.

Roth and Kopell (1973) suggested that in cases where the LPC may be difficult to identify, to avoid bias the value at 300 msec latency be used as the indicator of the of the LPC. The base to peak amplitudes at 300 msec are presented in Table 2; a  $t$  test for matched samples was significant,  $t(4)=3.31, p<.05$ .

TABLE 1

Latencies and Base to Peak Amplitudes  
of Components in Evoked Responses to Light

		N <sub>1</sub>	V	N <sub>2</sub>	LPC
Certain Condition					
Subject 1	Amp	-52.4	+69.6	-03.4	+50.6
	Lat	.14	.20	.25	.31
Subject 2	Amp	-57.6	+55.4	-32.6	+123.4
	Lat	.17	.21	.27	.33
Subject 3	Amp	-74.8	+187.2	-51.8	+16.2
	Lat	.12	.18	.26	.38
Subject 4	Amp	-72.1	+90.9	+66.9	+90.9
	Lat	.12	.18	.22	.24
Subject 5	Amp	+14.3	+184.3	+58.3	+90.3
	Lat	.15	.20	.24	.27
Uncertain Condition					
Subject 1	Amp	-104.1	+106.9	+58.9	+120.9
	Lat	.14	.20	.24	.30
Subject 2	Amp	-53.9	+100.1	+54.1	+155.1
	Lat	.16	.22	.26	.34
Subject 3	Amp	-34.1	+101.9	-31.1	+36.9
	Lat	.13	.18	.27	.33
Subject 4	Amp	-63.6	+161.3	+16.4	+96.4
	Lat	.14	.20	.26	.33
Subject 5	Amp	+11.9	+139.9	+80.9	+140.9
	Lat	.15	.19	.23	.27

TABLE 2  
Amplitudes of Responses to Light at 300 msec

Subject	1	2	3	4	5
Certain Condition	3.65	120.41	-4.76	14.90	38.28
Uncertain Condition	117.92	155.07	8.88	65.35	110.88

#### Responses to odor

As can be noted in Figure 8a-e, no response to odor is apparent in either condition for subjects 4 and 5, in the certain condition for subject 2, or in the uncertain condition for subject 1. Superimposition of the remaining traces is presented in Figure 9, illustrating that the small responses in each of these traces occurs at a peak latency of approximately 500 msec. This latency is similar to that reported by Finkenzeller (1966) and Allison and Goff (1967).

A t test for matched samples was calculated between the certain and uncertain conditions for the five subjects using the values at 500 msec. The result did not approach significance.

#### Responses to light and odor

The hypothesis that the evoked response to odor and the LPC to light would occur under similar conditions, the

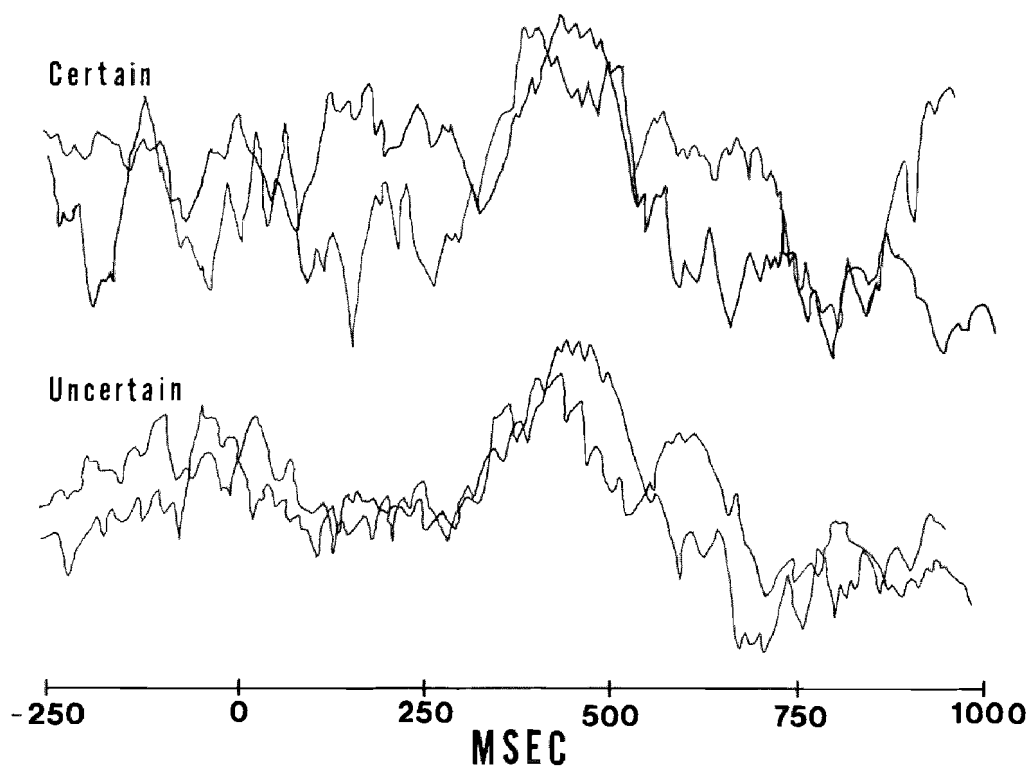


Figure 9. Odorant evoked responses. Note that the small responses in these traces are found at approximately 500 msec.

uncertain condition in this study, was not supported by the data. The amplitude of the LPC to light was significantly larger in the uncertain than certain condition, but the OER was not found exclusively or consistently in the uncertain condition.



## CHAPTER IV

### DISCUSSION

The LPC to light was significantly larger in the uncertain condition than in the certain condition, thereby replicating the results reported in a similar experiment by Sutton and his associates (1965). The odorant evoked response however was not found consistently or exclusively in the uncertain condition. And thus the contention that the response to odorants is similar to the LPC to stimuli of other modalities, in that the response is not obligatory but rather found only under various specifiable conditions, was not supported.

If, on the other hand, the response to odorants is obligatory, then the response should be found in both conditions for all subjects. In the present study responses were found in two of five subjects in the certain condition and in two of five subjects in the uncertain condition. In the study by Allison and Goff (1967) OER's were found in twelve out of twelve subjects under conditions which would indicate that the response is obligatory. There were a number of differences between their study and the present study which may account for the difference in results.

The first and perhaps most likely reason for the difference in results is found in the method of odor presentation. It is possible that in the present study the

method of odor presentation resulted in a variable interval between the presentation of the odorant and its arrival at the olfactory mucosa. Since the averaging of the responses was time-locked to the presentation, a variable time interval between the presentation of the odor and its arrival at the epithelia would have obscured the response. As described in the Method section, the subject breathed through her nose air that came from the olfactometer. This air was odorless except for brief intervals when odor was presented. The odor was presented manually when inspection of the subject's respiration record indicated that the subject was beginning to inhale. The air from the olfactometer continued to flow through the subject's nose throughout the respiration cycle; the subject was instructed to exhale through her mouth in order that the air would flow through her nose and out her mouth during exhalation. The air probably flowed somewhat faster during inhalation than during exhalation however, as the subject probably drew on the air during inhalation and obstructed the air flow somewhat during exhalation. The extent then to which the experimenter was unsuccessful in consistently delivering the odor as the subject inhaled, would have resulted in a variable time interval between the presentation of the odorant and its arrival at the olfactory epithelia. An odor delivery system which would be automatically operated contingent upon the subject's

inhalation and the appropriate interstimulus interval would eliminate or at least decrease this source of error. In the experiment reported by Allison and Goff a different method of odor presentation was used. The subject was instructed to breathe through his mouth as the air from the olfactometer flowed through his nose. Therefore the latency between the presentation of the odorant and its arrival at the olfactory mucosa would presumably be independent of the subject's respiration.

A second difference between the two studies was the duration of odor presentation. In the study by Allison and Goff solenoid valves were used to switch on and off the odor. This allowed automatic and precise control of stimulus duration; the length of odor presentation was .2 seconds. In the present study the odor was presented manually by turning a stopcock. The length of presentation, calculated by the computer, ranged from .3 to .6 seconds. Evoked responses are considered to be the response to the onset of the stimulus so the duration of the stimulus is presumed to be relatively unimportant. The light was also presented manually and therefore was subject to the same variation in duration.

A third difference between the studies was the length of the interval between presentations of the odorant. In the study by Allison and Goff the interval was five seconds;

in the present study the interval was longer and variable. The interval ranged from twenty seconds when odor trials were presented consecutively, to approximately 100 seconds when several light trials interposed odor trials. It appears unlikely, however, that making the interval longer and variable would diminish the response. In general investigators using visual, auditory, and somesthetic stimuli report enhancement of all potentials with longer intervals between presentations and with variable rather than fixed intervals (Regan, 1972; Shagass, 1972). However the effects of interval length and variable interval specifically on the response to odorants have not been determined.

A fourth difference between the two studies was the type of subject used. Allison and Goff did not specify the age or sex of their subjects, presumably they were middle aged. The present study used high school girls, ranging in age from 15-17. A number of recent reports have studied age and sex differences in averaged evoked responses, but unfortunately none have used the LPC for comparison. Looking at the earlier components, in general researchers have found that women have larger amplitude evoked responses than men (Buchsbaum, Henkin, & Christiansen, 1974). Dustman and Beck (1969) noted that in the visual evoked response the amplitude declined between the ages of 7 and 13-14 when an abrupt increase in amplitude occurred. Amplitude appeared

to stabilize at about age 16. An older subject sample than that used here would probably be advisable for investigatory work such as the present paper.

As discussed above, the failure of the present study to produce consistent results and thus to demonstrate whether or not the response is obligatory may be due to a methodological shortcoming. Four procedural differences between the present study and that by Allison and Goff which did produce consistent results, were discussed. The difference in procedure which seems most likely to account for the difference in results is the method of odorant presentation. The method of timelocking the odor presentation necessary for the averaging procedure may have been inadequate in the present study.

The next logical step in the study of OER's would seem to be an exact replication of Allison and Goff's experiment, using the same instrumentation and the same parameters. If OER's were consistently obtained, then the parameters, such as length of interstimulus interval, stimulus certainty and uncertainty, and subject sample could be varied to determine the effect on the OER and to allow comparison to evoked responses to stimuli of other modalities. If the results obtained by Allison and Goff were not replicated, then it is possible that their results were due to some artifact, to an unusual subject sample, or to unusual

psychological factors such as anticipation or extreme attentiveness.

## BIBLIOGRAPHY

- Allison, T., & Goff, W. R. Human cerebral evoked responses to odorous stimuli. Electroencephalography and Clinical Neurophysiology. 1967, 23, 558-560.
- Beidler, L. M., & Tucker, D. Response of nasal epithelium to odor stimulation. Science, 1955, 112, 76.
- Bickford, R. G., Jacobson, J. L., & Cody, D. T. R. Nature of averaged evoked potentials to sound and other stimuli in man. Annals of New York Academy of Science, 1964, 112, 204-223.
- Buchsbaum, M. S., Henkin, R. I., & Christiansen, R. L. Age and sex differences in averaged evoked responses in a normal population, with observations on patients with gonadal dysgenesis. Electroencephalography and Clinical Neurophysiology, 1974, 37, 137-144.
- Davis, H., Osterhammel., Wier, C. C., & Gjerdingen, D. B. Slow vertex potentials: interactions among auditory, tactile, electric and visual stimuli. Electroencephalography and Clinical Neurophysiology, 1972, 33, 537-545.
- Dustman, R. E., & Beck, E. C. The effects of maturation and aging on the waveform of visually evoked potentials. Electroencephalography and Clinical Neurophysiology, 1969, 26, 2-11.
- Finkenzeller, P. Gemittelte EEG-Potentials bei olfaktorischer Reizung. Pflugers Archiv fur die Gesamte

Physiologie des Menschen und der Tiere, 1966, 292.

76-80.

Grundvig, J. L. The effect of temperature on olfactory thresholds. Unpublished doctoral dissertation, University of Utah, 1966.

Grundvig, J. L., Dustman, R. E., & Beck, E. C. The relationship of olfactory receptor stimulation to stimulus-environmental temperature. Experimental Neurology, 1967, 18(4), 416-428.

Hays, W. L. Statistics. New York: Holt, Rinehart and Winston, 1963.

Jasper, H. H. The ten twenty electrode system of the international federation. Electroencephalography and Clinical Neurophysiology, 1958, 10, 371-375.

Karlin, L. Cognition, preparation, and sensory evoked potentials. Psychological Bulletin, 1970, 73(2), 122-136.

Lindsey, J. W. The auditory evoked potential in man: a review. Journal of Life Sciences, 1971, 1, 91-110.

Regan, D. Evoked potentials in psychology, sensory physiology, and clinical medicine. London: Chapman and Hall, 1972.

Ritter, W., Simson, R., & Vaughan, H. G., Jr. Association cortex potentials and reaction time in auditory discrimination. Electroencephalography and Clinical



- Neurophysiology 1972, 33, 547-555.
- Roth, W. T., & Kopell, B. S. P<sub>300</sub> - an orienting reaction in the human auditory evoked response. Perceptual and Motor Skills, 1973, 36, 219-225.
- Shagass, C. Evoked brain potentials in psychiatry. New York: Plenum Press, 1972.
- Smith, D. B., Allison, T., Goff, W. R., & Principato, J. J. Human odorant evoked responses: effects of trigeminal or olfactory deficit. Electroencephalography and Clinical Neurophysiology, 1971, 30, 313-317.
- Sutton, S. The specification of psychological variables in an average evoked potential experiment. In E. Donchin & D. B. Lindsley, (Eds.), Average evoked potentials. Washington D. C.: NASA SP-191, 1969.
- Sutton, S., Braren, M., Zubin, J., & John, E. R. Evoked potential correlates of stimulus uncertainty. Science, 1965, 150, 1187-1188.
- Sutton, S., Tueting, P., Zubin, J., & John, E. R. Information delivery and the sensory evoked potential. Science, 1967, 155, 1436-1439.
- Tucker, D. Olfactory, vomernasal, and trigeminal receptor responses to odorants. In Y. Zotterman (Ed.), Olfaction and taste I. London: Pergamon Press, 1962.
- Tucker, D. Physical variables in the olfactory stimulation process. Journal of General Physiology, 1963, 46, 453-489.

- Vaughan, H. G., Jr. The relationship of brain activity to scalp recording of event-related potentials. In E. Donchin & D. B. Lindsley (Eds.), Average evoked potentials. Washington D. C.: NASA SP-191, 1969.
- Vaughan, H. G., Jr., & Ritter, W. The sources of auditory evoked responses recorded from the human scalp. Electroencephalography and Clinical Neurophysiology, 1970, 28, 360-367.
- Williamson, P. D., Goff, W. R., & Allison, R. Somatosensory evoked responses in patients with unilateral cerebral lesions. Electroencephalography and Clinical Neurophysiology, 1970, 28, 566-575.